



# HALESIS ou l'étude de phénomènes lumineux transitoires par imagerie hyperspectrale embarquée sous ballon

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# FEASIBILITY OF HIGH ALTITUDES LUMINOUS EVENTS STUDY BY INFRARED SPECTRO-IMAGERY EMBEDDED IN A STRATOSPHERIC BALLOON.



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## Abstract

HALESIS (High Altitude Luminous Events Studied by Infrared Spectro-imagery) is an innovative project based on hyperspectral imagery. The purpose of this experience is to measure the atmospheric perturbation in the minutes following the occurrence of Transient Luminous Events (TLEs) from a stratospheric balloon in the altitude range of 20 to 40 km. We present the preliminary study that has established the feasibility of the project.



## I – Motivation and scientific context

- 1989: 1<sup>st</sup> record of transient luminous events (TLEs) in the high atmosphere.
- => Demonstration of the existence of another interaction processes between the different atmospheric layers (troposphere, stratosphere, mesosphere and ionosphere).

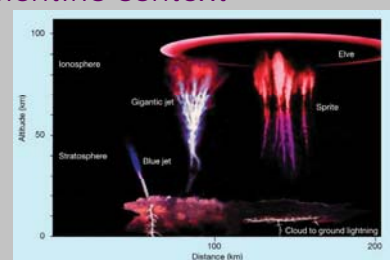


Figure 1: Lightning related TLEs (Pasko V P 2003 Electric jets Nature 423927-9)

### Consequences :

- interaction processes between the different atmospheric layers, which was not considered before
- impact not yet quantified
- chemical processes involved having potential broader consequences

Name	Altitude	Duration
Blue Jets	10-40 km	A few 100 ms
Gigantic Jets	10-90 km	A few 100 ms
Sprites	50-90 km	10 ms
Elves or Halos	70-90 km	1 ms

Tableau 1: Altitude and duration of TLEs (Pasko V P 2010 JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, A00E35)

## II – HALESIS PURPOSE

- The presence of oxygen atoms in electronic excited states has an impact on ozone chemistry.
- Atomic or molecular species excited in electronic or vibrational states can induce various chains of chemical reactions and local enhancements of the concentrations of  $O_3$ ,  $NO_x$  ( $NO+NO_2$ ),  $NO^+$ ,  $OH$ ,

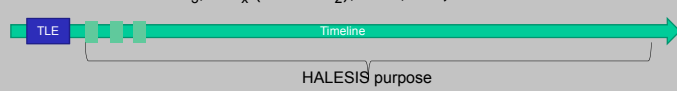


Figure 2: HALESIS experiment timeline.

### HALESIS PURPOSE:

What's happened in the minutes following the events;  
To **measure the effect of these events on stratospheric chemistry** by retrieving the concentration of species potentially produced or perturbed ( $NO_x$ ,  $O_3$ ,  $OH$ , ...)  
To monitor the **vibrationally excited chemical reactions** associated with TLEs.

## III. Physical Processes at the origin of TLE

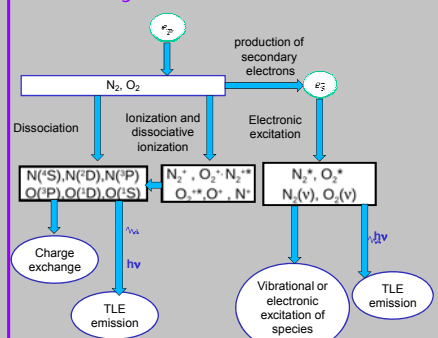


Figure 3: Physical processes at the origin of TLE.

- An electrical perturbation caused by a thunderstorm can trigger a discharge above the clouds in the upper layers of the atmosphere.
- The associated energized electrons excite, ionize or dissociate the major constituents  $N_2$  and  $O_2$  of the atmosphere leading to atomic, molecular, or ionic species.
- When relaxing to lower energy states, visible photons are emitted.

## IV – Instrumental setup

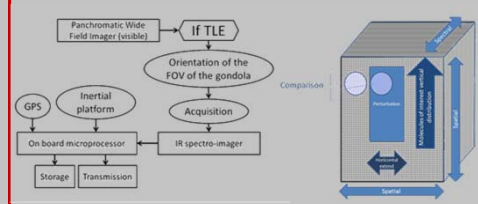
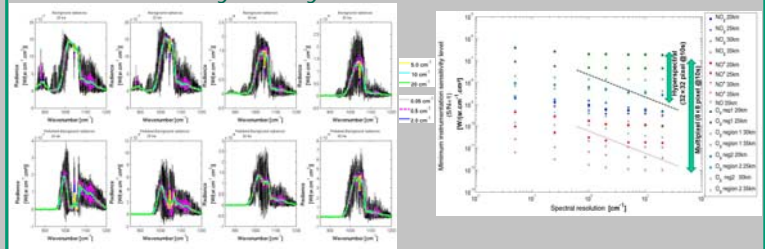


Figure 4: HALESIS instrumentation principle and interest of the use of an hyperspectral imager.

Spectro-imagery is a combination of imaging and spectroscopy. It allows for acquiring images that are spectrally resolved.

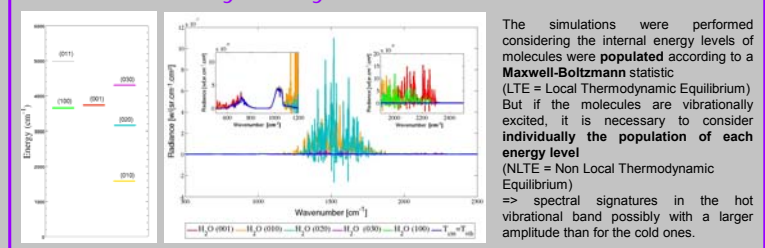
- Horizontal spatial dimension: comparison between central and edge pixels.
- Vertical spatial dimension: vertical distribution of species.
- Spectral dimension: depends on the target species produced or perturbed ( $NO$ ,  $O_3$ ,  $NO_2$ ,  $NO^+$ )

## V – Feasibility study : fundamental bands

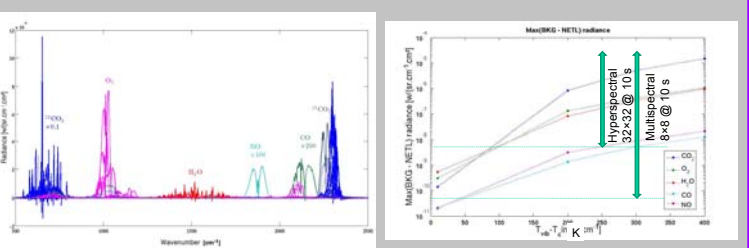


- Signature of the  $O_3$  effect on "easily" detectable in the TIR
- $NO_2$  and  $O_3$  effect signatures requires multipixel medium resolution concept

## VI – Feasibility study : hot bands



The simulations were performed considering the internal energy levels of molecules were populated according to a **Maxwell-Boltzmann** statistic (LTE = Local Thermodynamic Equilibrium). But if the molecules are vibrationally excited, it is necessary to consider **individually the population of each energy level** (NLTE = Non Local Thermodynamic Equilibrium). => spectral signatures in the hot vibrational band possibly with a larger amplitude than for the cold ones.



- $O_3$ ,  $H_2O$ ,  $CO_2$  signatures « easily » detectable in the MIR;
- $NO$  and  $CO$  signature detectable with a multipixel concept.

## VII – Conclusion and Outlook

- Very poor information on the impact of TLEs on the chemical composition of the stratosphere;
- We are currently establishing the feasibility of an **innovative project** to measure the **impact of TLEs on atmospheric compositions**.
- Need to simultaneously acquire spectral measurements in disturbed and undisturbed atmosphere, at different time, and at different altitudes -> **hyperspectral imaging** !

- Preliminary simulations** showed that the order of magnitude expected to detect a disturbance are consistent with detection limits of
  - A commercial spectro-imager to (950-1075  $cm^{-1}$ ) for  $O_3$
  - A multipixel spectrometer (1675-1750  $cm^{-1}$ ) for  $NO$
- Need to **explore the hot bands** to probe more species and more information;
- Need to **explore innovative FTS instrument concepts** for an acquisition frequency and sufficient sensitivity (GLORIA/IMK, SIELETERS/ONERA, ...)

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